# Decision Based Wireless Sensor Network Operational Design

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***Abstract*: Wireless Sensor Networks is emerging to be an area of huge potential with many researchers and engineers working to establish its application in areas of military surveillance and areas that are risky or difficult for humans to reach. This paper comprises of a method that has been devised with the aim of developing effective, universal and intelligent wireless sensor network systems that are able to take appropriate decisions in the time of need.**

***Keywords*: Wireless sensor networks, clustering, block formation, intelligent systems**

## I. Introduction

The strategy to divide sensor nodes into appropriate type and number of clusters remains to be a challenging task. The main challenges that are faced by the researchers comprise of the scarce availability of resources such as battery and memory, and the constraints posed by their limited computational capability and energy utility. Resultantly, an optimized and judicious utilization of resources has become the main concern of present-day research. Considering these factors, a solution has been proposed in this paper that utilizes the available resources optimally and at the same time meets the goal of effective sensing operation.

## II. Sensor Network Setting

### *A.* Objective

This paper presents an operational design of wireless sensor network system for surveillance applications such as that of temperature or movement in an area. The design extends the application of LEACH (Low Energy Adaptive Clustering Hierarchy) protocol in order to incorporate dynamic cluster formation and applies the concept of mutable clusters. The objective of this paper is to introduce a method that provides for optimum sensor coverage of a field along with the ability to last for the maximum duration.

### *B.* Random Distribution Of Nodes

The nodes are assumed to have been dropped aerially on a piece of ground where surveillance has to take place. While the nodes are being distributed, one cannot ensure uniform distribution of nodes dropped in a particular area. The denseness of nodes can thus vary from place to place where one patch of ground can be densely populated while another one sparsely. It has therefore been assumed that the nodes are randomly distributed on the ground. If not taken care of appropriately, such kind of distribution can render the sensing operation less effective by producing a lot of redundant information from densely populated regions while the sparsely populated ones run the risk of dying out early and also could be missing out coverage of some area.

One of the nodes has to take up the status of a parent after which it would carry out a set of crucial actions. How these nodes are selected and what responsibilities they are supposed to undertake have been elaborated upon in section V.

The nodes make use of appropriate routing techniques in order to transfer signals and sensor observations to the base station. These routing techniques can be decided upon dynamically on the basis of node orientation and closeness to the base station.

The nodes should also have the capability to destroy the data when they are left with a certain energy so low that they would be unable to participate further in the process. This should be done in order to avoid information leakage.

## III. Approach

The approach that has been adopted is to divide the field of land on which nodes are distributed into blocks of land of any shape. For the purpose of illustrating the concept, we are considering the blocks to be rectangular in shape. The reason behind adopting this approach is that clusters, which are a set of nodes, cannot be associated with an area accurately. The underlying patch of land, therefore, needs to be given an identity in order to be able to distribute the nodes uniformly over it. An inner border is associated with every block, which identifies the nodes in the border area and facilitates the communication of one cluster with the neighboring ones. The nodes, assumed to be mobile, should relocate themselves so as to achieve the goal of uniform distribution.

## IV. Terminology

- In this paper, the block borders are being referred to as longitudes and latitudes. They should not be mistaken with the geographic longitudes and latitudes, which are referenced according to the geographic poles. Here, the frame of reference can be chosen to be with respect to anything and in any orientation as per convenience.

- The word cluster should not be confused with the word block. A block refers to a patch of land that is produced using the intersection of longitudes and latitudes. On the other hand, a cluster refers to a group of nodes that have a common cluster head.

Initially, all the nodes lying within a block belong to one cluster. As the process progresses, the nodes lying on the border region of a block may belong to neighboring clusters.

- The inner block density can be categorised into excessive, requisite or sparse. This information, stored in the respective cluster head, has to be updated regularly.
- The area of the block lying between the outer and inner border is termed as the border area of the block. The area of the block lying inside the inner border is termed as the inner area of the block.

## V. Parent Node Formation

Each node has been provided with a unique ID which maybe encrypted based on the requirement. The IDs have to conform to a set of rules that are pre-defined by the designer in order to avoid the breach of security. A sequence has to be decided by the designer according to which a priority number is to be designated to every node. This priority number has to be embedded in the node ID. According to this sequence, the nodes would take up the role of the parent. The node with the highest priority declares itself as the parent in the beginning of the process.

Upon falling on the ground, every node has to identify its priority number from its ID (which has been stored in it at the time of configuration) and identify the time its has to wait for before declaring itself as the parent. The node with the, say, second priority number has to wait for a certain period of time and then declare itself as the parent. If, for some reason, it is unable to declare and broadcast itself as the parent in the maximum specified time, then the node, next in priority queue, has the impetus to declare itself as the parent and the process continues similarly. After the end of this wait period, the node, second in priority, cannot declare itself as the parent node. The wait periods have to be such that there is no more than one node declaring itself as the parent node in the entire broadcasting duration. A node can become the parent as long as it conforms to possessing energy corresponding to the threshold $E_{p1}$ (elaborated upon in section VIII).

Every node has the capability to become the parent node. The nodes take up the call to become the parent in the sequence of their priority number. The sequence can be alloted to the nodes randomly because we are assuming the nodes to be of the same capability in the beginning.

Upon, deciding to become the parent, the node has to modify its ID to incorporate a characteristic that uniquely establishes the ID to be a parent node ID. This way the other nodes will get to know that a message has been delivered by the parent node.

## VI. Clustering of Nodes

Upon landing on the ground, the distributed nodes have to identify their locales. It has to be pre-decided, as to whether these locales have to be global (as in the case of GPS) or relative to a particular location. The decision can be taken based on the requirement and has to be pre-coded into the nodes.

The parent node has to route a message to every node in its neighborhood. This message contains the locales of the parent node and its ID. The parent node then has to command these neighboring nodes to forward the message to their own neighboring nodes. Like this, the message will be propagated to all the nodes in the system. Upon receiving the message, every node has to transmit its ID and locales back to the parent node by remembering the path to it.
Using these locales, the parent node identifies the stretch of land on which all nodes have been distributed. It then divides the land into several blocks based on the radio range of the nodes. It has to decide upon the inner border of the blocks. The length and breadth of the blocks, and its border area width have to be such that the farthest possible distance between a cluster head and a normal cluster node should be within the radio range of nodes. The blocks, and their inner and outer boundaries remain fixed as have been decided by the parent node and they are decided once in the entire process. The radio range has to be decided upon at the time of designing of sensor nodes and the information about it has to be stored priory in the all the nodes.

To start with, all the nodes in a block form one cluster. It can later on be mutated to include the border nodes of neighboring blocks. The parent node then creates a table containing the information about every block, its cluster head and the nodes in the block. The information is routed in such a manner that every cluster head obtains the information about the nodes in its cluster.

### *A.* Selection of Cluster Head

Initially, the cluster head has to be selected by the first parent node. The parent node selects the node nearest to the center of every block as the initial cluster head. This has been done so that initially the neighboring cluster heads are able to communicate with each other directly. Later on, they can communicate with each other via the border nodes in a bid to transfer the message to the base station or to transfer nodes.

Later on, the responsibility can transfer to any other nodes in the inner region of the block based on an algorithm which can, for examlple, be round robin where the nodes take up the role of the cluster head for a fixed period of time after which they have to transfer the role to the next node in rotation. It would be preferred that the next cluster head be the next nearest node to the center. The existing cluster head should give up the role only when a new candidate has been identified and the responsibilty has been endowed upon it.

If no such node exists in the inner region of the block, then the current cluster head has to request for nodes from the neighboring inner blocks. The border nodes can be transfered if they are excessive in number, otherwise they shouldn't be in order to conserve them and their energy (as it is being consumed in mediating between cluster heads on a frequent basis).

Ideally, such a situation should not arise becauses as soon as the inner block has the density of nodes below threshold $D_{innerblock}$ (explained in section VIII), it should comand the border nodes to communicate the same with the neighboring cluster heads. If its energy is about to end, that is, it is below $E_{ch2}$ (explained in section VIII), then it is bound to command one of the border nodes to take a place in the inner region of the block and become a cluster head.

## VII. Key Points on Implementation

- When the energy of the parent node is below a threshold ($E_{p2}$, as explained in section VIII), it would have to give up its "parent" status and command the next priority node to become the parent node. For this, a communication route has to be identified between the existing parent node and the next priority node and then the message has to be transmitted via the route. An acknowledgement has to be transmitted from the next priority node upon taking up the "parent" status confirming the same to the existing parent node. Upon receiving this signal, the existing parent node has to give up the status and start to behave like a normal node. This means that for a period of time, referred to as the switching time, there will be two parent nodes. This time serves as an overhead and should be minimized using effective routing techniques.

- After having been dropped, the first priority node has the impetus to start the process by declaring itself as the parent. It would have to compare its energy with the initial threshold that has been pre-decided by the designer. Unfortunately, if this node was damaged while being dropped or has already run out of energy in that its energy is below this threshold, then it is unable to declare itself as the parent. For that, a wait period has to be defined after which the second priority node will declare itself as the parent and the process will continue in a similar manner.

- A border node cannot be a cluster head in general. But in extreme cases, for example, when there is no other node alive in the inner region of the block, it has to become one provided it changes its position to a place inner to the block.

## VIII. Threshold Quantities

The threshold quantities that have to be identified are as follows:

- $E_{p1}$: This energy, referred to as the parent node first energy threshold, is the amount of energy that a node needs to have prior to becoming the parent node in order for the role to be transferred to it. If no such node is left in the system, and a parent node is still needed, then the system becomes unstable. In that case, the nodes have to do with whatever energy they are left with.

This energy has to be dynamically calculated by the existing parent node according to the amount of work that is remaining to be done by a parent. If the next in priority node does not satisfy this constraint then this threshold is updated by the existing parent node, which then communicates the same way with the node whose priority is second from his, and so on.

- $E_{p2}$: If the energy of the parent node is below this threshold, then it has to forgo its right as the parent and command the node, next in priority, to take the role of the parent. $E_{p2}$ should be lower than $E_{p1}$.

- $D_b$: A node has to lie within a threshold distance on either side of a border in order to qualify as a border node. This distance has to be calculated dynamically according to the radio range of the nodes. The distance has to be such that the border nodes are able to communicate with the farthest possible cluster head across that particular border adjacent to which the two blocks lie. A node lying at the distance of $D_b$ from the vertex of the block along the diagonal has to take the decision as to whether it will communicate with cluster heads of both the adjacent blocks or with only one of them.

- $E_{ch1}$: This amount of energy has to be possessed by a node in order for it to be able to take up the role of the cluster head. This energy has to be calculated based on the minimum energy required by atleast one task to be carried out successfully.

- $D_{innerblock}$: This is threshold on density of the inner region of the block. If the inner block density has reached below this threshold, then the cluster head has to command the border nodes to communicate with neighboring cluster heads to transfer some nodes to its own inner block.

- $E_{ch2}$: If a cluster head is left with this amount of energy and no inner node is available, then it has to urgently transfer its role to a border node. This can be done by broadcasting this information to all the border nodes. A border node has to take the decision based on its left over energy as to whether it is eligible to become the cluster head. The current cluster head then picks up one amongst the eligible candidates and selects it to be the cluster head by transfering the responsibility to it.

If a border node is also not available and the cluster head dies out, then the block becomes ineffective. This can be sensed by the neighboring blocks' border nodes and then they can inform their cluster heads about the same. One of the cluster heads can establish a route to the base station and can inform it as well. The routing to the base station can be done by using cluster heads and the border nodes. Then the base station decides as to how to recover the block.

- Density thresholds A, B and C: Three node density thresholds for a block have to be identified using which its concentration can be categorised into either of excessive, requisite or sparse. The density has to be measured in the units: Number of nodes/block area. There is a lower bound to the 'sparse' category below which the cluster can be considered to be in urgent need of nodes.

These threshold values can be updated dynamically based on the remaining energy of the nodes with the aim to utilise their energy to the fullest.

## IX. Decision Characteristics

The nodes have to take several decisions at various stages of the operation. The decisions can be taken either in an individual manner or can be collective based on the dynamics of the situation. A decision analysis has to be carried out according to various factors and the requirement of the system.

*1)* The border nodes are given special privileges as to be able to decide which cluster they want to be in and at what instant of time. The nodes lying on the border or within a certain distance from the border can decide to communicate with either of the cluster heads (lying in the block with which that border is shared). They can start to communicate with the cluster head of a particular cluster only once they have decided to belong to that particular cluster without the need to change their position or block. The decision can be taken based on energy left in it and proximity to the current cluster heads.

2) The decision to transfer nodes from one block to another has to be jointly taken by individual nodes and the cluster head. This decision depends upon internal and external factors. External factors include the likes of weather conditions and ground terrain, and the internal factors include battery backup. Overall it depends upon affordability to travel such distances and the productivity outcome associated with the action. This decision should not lead to an excessive drain of energy in the donor cluster. Also, no two nodes should coincidently land on the same spot or too near to the existing ones.

## X. Energy Consumption Optimisation

The aim of energy consumption optimisation has been achieved by incorporating the concept that some nodes are being transferred from a densely packed cluster to a sparse one at a suitable time when the sparse cluster is about to be exhausted of all its energy. Such a transfer of nodes can take place, for example, when majority of nodes in the sparse cluster have died out. This can take place by the sparse cluster head communicating to its border nodes about the same which can later share the same information to the respective neibhoring cluster heads as a request for more sensor nodes. The neighboring cluster heads will then take a call as to whether it would be appropriate for them to donate nodes as per their current density status. In this manner, the node will be able to travel to far off blocks bit by bit. This way a more uniform distribution of nodes can be achieved for a longer period of time.

The cluster heads can decide on the frequency of sensing of its cluster nodes based on the density of their blocks. The blocks with high density can go for low frequency sensing in order to avoid redundanct information and optimise energy whereas the blocks with low density can increase their sensing frequency to cover a larger area and sense distinct features.

## XI. Assumptions

- Every node has been assumed to have the same computational and energy capability at the start of the process.
- All the nodes in the network are mobile and are can move from one cluster to another. They can also moves within the cluster if required.
- The radio range of the nodes remains fixed throughout the process.
- The distribution is such that there is no need to transfer the nodes from a denser block to a sparser one in the beginning of the process.

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